U.S. POTATO DEMAND: STATIC AND DYNAMIC CHARACTERISTICS

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Presented at AAEA meetings, Pullman,
July 29 - Aug. 1, 1979.

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Abstract

Aggregate demand relationships for the U.S. potato industry are estimated by two-stage least squares. Demands were found to be price inelastic suggesting that abrupt changes in production cause major inverse price effects. Secular demand shifts are relatively rapid. Together these suggest opportunities for expanded production but a need for careful planning to avoid price depressing effects from even moderately excessive production growth.

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Introduction

The main objective of this paper is to report econometric parameter estimates for aggregate domestic demand schedules in the U.S. potato market. These results represent part of a larger research project designed to assess the impacts associated with increasing potato production in the Pacific Northwest (PNW)[1]. In recent years, the PNW has registered significant gains in its share of the total U.S. potato market. Among the set of possible explanations to account for this increase, particular interest has focused on the development of new and irrigable land. Significant increases in available land suggest the production of high value crops, such as potatoes, is likely to increase. If significant increases in production were to occur, several fundamental marketing issues should be examined. Of critical concern to Northwest producers is their ability to sell expanding production without depressing local or national prices. A corollary concern is the supply response and price effects for competing producing regions in the face of rising production in the PNW.

In order to examine the extent of possible impacts, an econometric model was formulated to provide a historical assessment of the behavioral forces operating in the markets for potatoes. The historical period of concern to this research was the 1955-1975 period. The modeling process entailed: (1) the specification of regional supply response equations; (2) the formulation of aggregate demand relationships; (3) the specification of a set of relationships linking national and regional prices; and (4) the use of the estimated structural model to simulate solution results given alternative rates of growth in irrigated acreage for the PNW.

The model consists of a 46 equation structure in which the supply response submodel is a segmentable component from the complete model. The structure models the determination of planted acreage, yield, production, and farm prices in the PNW and in five other producing regions which compete with Northwest production. A subset of the project, which is the focus of this paper, models national demand relationships for potatoes used in processing, fresh consumption, and livestock feed.

Conceptualization of Demand Relationships

Disappearance data indicate the major utilizations of potatoes can be identified as: (1) fresh consumption (Q^d_{FR}); (2) processed products (Q^d_{PD}); and (3) livestock feed (Q^d_{FD}). Human food consumption typically accounts for three-fourths of total disappearance with the remaining one-fourth utilized by livestock feeders, seed stock users, and losses due to shrinkage factors.

Fresh and processed forms have experienced persistent but opposite secular trends since mid-century. Per capita fresh consumption currently is one-half of its level in 1950. Conversely, per capita consumption of processed potatoes increased 11-fold during the same time span.[2] The trend toward consumption of processed products reflects a shift of consumer preferences in favor of convenience foods. Conventional demand theory states quantity demanded for each use depends on its own price, the price of substitutes, consumer's income, and tastes and preferences. Attempts to estimate separate retail demand schedules for fresh and processed uses were precluded due to the lack of separate retail price data for these forms.[3] An alternative formulation is to estimate derived farm-level demand relationships by replacing

retail fresh and processed prices with national farm price ($FP_{U.S.}$) and include a separate explanatory term to represent the costs of marketing services which affect the margin between retail and farm price. For fresh demand, these costs were proxied by an index of hourly wage rates in wholesale and retail trade ($IWR_{U.S.}$). Research conducted by the National Commission on Food Marketing indicates labor costs are the most important cost component in the movement of fresh fruit and vegetable products through the marketing channel. Marketing costs for processing potatoes were represented by the Industrial Wholesale Price Index (IWPI) since the potato is physically transformed between the farm gate and the ultimate consumer. It is assumed the outlays for goods and services associated with processing plant operations, as well as other marketing costs, will be reflected by the IWPI. The increase in consumer preference for convenience in food products was proxied by the fraction of women employed in the labor force ($WLF_{U.S.}$). Previous findings suggest and preliminary empirical results of this study confirm that no substitutes could be identified which significantly influence the demand for potatoes.

In this study income was defined as national disposable income (Y). Preliminary testing produced better results when fresh and processed quantities and income were specified on a per capita basis. Prices and income were deflated by the Consumer Price Index (CPI, 1967 = 1.0) to incorporate the assumption of no money illusion in demand response.

Under the conceptualization adopted here, season average farm price and annual levels of the three components of demand are simultaneously determined once total production and other predetermined variables are given. Therefore, each structural demand equation contains two

simultaneously determined variables. Two-stage least squares (2SLS) provides a consistent estimation technique for single equations within such a system. Fresh and processed demands were estimated as linear functions of the explanatory variables. Feed demand was estimated as an exponential function of undeflated farm price.

Model Results

Two-stage least squares estimation results for the three demand relationships are presented in Table 1. The standard error of estimate is 2.8 percent of the mean for fresh consumption and 9.3 percent for processing potato consumption suggesting that the errors are generally small relative to demand levels. Comparatively, errors in estimating feed demand are larger but this component of demand is a small fraction of total potato demand. All parameter signs agree with a priori expectations. In particular, the expected negative coefficient on the $WLF_{U.S.}$ factor in the fresh equation and the expected positive coefficient on the same variable in the processed equation were obtained. The coefficients on real disposable per capita income in the fresh and processed equations are positive but insignificant; nevertheless the variable is retained in the equations since there is strong theoretical justification for its inclusion in the relationships. The results in Table 1 were converted to elasticities evaluated at the means of the data and these elasticities are presented in Table 2.

Demands were found to be relatively price inelastic, suggesting that abrupt changes in production would have major inverse price effects. The estimates of price elasticities in this study are in general agreement with the values obtained by Gray, Sorenson, and Cochrane (2), Fox (1), Simmons (6), and Hee (3). Estimated income

elasticities indicate that potato demand is relatively insensitive to income changes although the income effect is more pronounced on processed demand than fresh potato demand. Processed demand is also relatively more responsive to changing preferences for convenience foods. A one percent increase in $WLF_{U.S.}$ results in nearly a 5 percent increase in processed demand. Margin elasticities indicate a one percent increase in deflated wage rates reduces fresh demand by 1.36 percent while industrial wholesale prices have little effect on processed demand.

Secular Trends in Demand Shifters

Estimated coefficient values provide guidelines in appraising the rate of demand growth caused by certain explanatory forces identified in demand theory as "demand shifters".[4] An estimate of the average rate of growth for each shifter can be utilized in the demand model to provide some measure of the ability of consumers to assimilate output increases.

In order to estimate the average annual change in demand for food products due to secular trends, we focus attention on the estimated coefficient values for two of the exogenous influences as displayed in (1).

$$(1)\qquad \begin{aligned} Q^d_{FR}/N &= -2.4452\ WLF_{U.S.} + .0318\ Y/(N\cdot CPI) + \ldots \\ Q^d_{PD}/N &= 6.8953\ WLF_{U.S.} + .1200\ Y/(N\cdot CPI) + \ldots \end{aligned}$$

An equation defining total food demand for potatoes can be constructed as the sum of the above two equations as displayed in (2).

$$(2)\qquad Q^d_{HC}/N = 4.4501\ WLF_{U.S.} + .1518\ Y/(N\cdot CPI) + \ldots$$

The dependent variable represents the quantity of potatoes demanded for human consumption per person. The coefficients of $WLF_{U.S.}$ and $Y/(N \cdot CPI)$ in (2) are sums of coefficients of these respective variables appearing in the fresh and processed demand equations. Among other things we note that while changes in labor force composition have reduced per capita fresh demand, the net effect on total potato demand is positive.

The average annual rate of change in the two demand shifters may be obtained by regressing each factor on time. For the sample period, the estimated linear relationships are:

$$\begin{aligned} WLF_{U.S.} &= .2859 + .0033t \qquad R^2 = .988 \\ Y/(N \cdot CPI) &= 1.9515 + .0630t \qquad R^2 = .959 \end{aligned} \tag{3}$$

Thus, the average yearly changes in $WLF_{U.S.}$ and $Y/(N \cdot CPI)$ have been approximately .0033 and .063, respectively. Expressions (2) and (3) can be used to obtain the average attributable to changes in $WLF_{U.S.}$ and $Y/(N \cdot CPI)$.

$$\begin{aligned} \frac{d[Q^d_{HC}/N]}{dt} &= (4.4501)(.0033) + (.1518)(.0630) \\ &= .0242 \text{ cwt annually} \end{aligned} \tag{4}$$

As a final consideration, the shift in the demand schedule induced by changes in population must be examined. Linear regression results indicate that population increased during the sample period at an average annual rate of 2.44 million people per year.

These results can be collected to estimate the annual rate at which the potato demand schedule has been shifting due to population, real per capita income, and changing preferences for convenience foods. To do so, we make use of the relationship given in expression (5).

$$(5) \qquad \frac{dQ^d_{HC}}{dt} = \frac{d[Q^d_{HC}/N]}{dt} \cdot N + \frac{dN}{dt} \cdot \frac{Q^d_{HC}}{N}$$

Evaluation of (5) is straightforward. From equation (4) the estimated annual rate of change in per capita demand is .0242. The estimated 1955-75 average rate of change in population is 2.44. If 1955-75 mean values for the population and per capita food demand variables are used, the collective effect of demand shifts is to increase demand at an average annual rate of 3.25 percent or approximately 7.5 million cwt per year. If 1972-76 mean values for population, per capita demand, and rate of change in population are employed, the estimated combined effect is to shift the total demand schedule outward about 2.25 percent annually, or about 8 million cwt per year.[5]

The structure of potato demand as suggested by the above findings provides a mild but interesting contrast to the nature of demand relationships for many food products. The static theory of individual consumer demand suggests that the sum of all price and income elasticities is zero. For a commodity having few substitutes, one usually expects to see the price elasticity and income elasticity about equal in magnitude and opposite in sign. If the commodity is not a luxury good, then both of the elasticities are expected to be less than 1.0 in absolute value. These are definitely the findings for fresh potato demand in this study, and to a lesser degree they apply to demand for the processed product as well. But to extend the argument, if the demand relationship describes behavior in a relatively mature economy, and one where exports are negligible, one typically expects to see a slow rate of shift of the demand schedule for such a commodity. The income effect, usually a principal demand shifter, will be damped via the modest income elasticity; while population growth, another

principal shifter, is usually slow in such societies. Again these conditions prevail with respect to potato demand in the U.S. Population growth is currently below one percent per year, exports are very small in most years, and as noted above, potato demand is quite inelastic with respect to income. However, in the case of U.S. potato demand, the shift of preferences in favor of convenience foods appears to provide a substantial added component of demand growth. The rates of shift reported above are about one-third greater than would be the case if the rate of change in per capita demand calculated in equation (4) reflected only per capita income growth. The result is a demand structure which, though quite inelastic with respect to price, is nonetheless showing a pronounced secular shift to the right.

Implications for Industry Expansion Prospects

The above findings pose an interesting challenge to an expansion-minded section of the U.S. potato industry such as the PNW. Opportunities for a considerable expansion of production pursuant to irrigation development appear to exist if, as seems likely, the secular shift in potato demand continues. The most rapid shift is occurring in demand for processed potato products, and the Northwest has an established processing industry. But concurrently, the price elasticity of demand suggests that any rate of growth in production even modestly greater than the rate of growth in demand can have severe price depressing effects. Historically, year to year price variability in potato markets has been relatively large. There seems little doubt that a principal reason is that the small price elasticity of demand magnifies the effect of minor production variations into relatively large price changes.

It is likely that these characteristics will continue to be present in the future structure of potato demand.

Clearly, actions of producers in competing supply areas will also affect the expansion prospects of the PNW, and they are being investigated simultaneously with the demand analysis reported here. However, it is apparent that the industry will continue to face a challenging problem as it seeks to take advantage of expanding potato demand while at the same time restraining the rate of production growth within the rather narrow limits that avoid extreme price variability and industry disruption. Even moderately excessive rates of production expansion could depress prices substantially.

Footnotes

[1]The Pacific Northwest is defined as comprising three states: (1) Idaho; (2) Washington; and (3) Oregon. Currently these states grow approximately 50 percent of all potatoes produced in the U.S.

[2]This information was gleaned from Hee (3), Vegetable Situations (7), and various conversations with USDA researchers.

[3]For much of the sample period, the retail price reported by the Bureau of Labor Statistics (BLS) represented a weighted average of fresh and processed prices.

[4]Demand theory identifies three principal forces which change demand levels: (1) population; (2) income; and (3) tastes and preferences. The first two influences are included directly in the equations. It is assumed in this study a reasonable measure of changing tastes and preferences is the $WLF_{U.S.}$ factor. These forces act to shift the entire demand schedule. The actual quantity demanded either before or after the shift depends on price.

[5]This result reflects an average annual increase in demand using mean value data and cannot be associated with particular year-to-year changes during this period.

TABLE 1. 2SLS Parameter Estimates and Related Statistics for Potato Demand Equations

Dependent Variables	Independent Variables						$S_{y \cdot x}$	S_y	Dependent Var. Means
	Constant	$FP_{U.S.}/CPI$	$WLF_{U.S.}$	Y/N·CPI	IWR/CPI	IWPI/CPI			
Q^d_{FR}/N	2.5572	-.0402	-2.4452	.0318	-1.0718		.0206	.148	.746
	(10.999)	(3.689)	(2.003)	(.452)	(5.229)				
Q^d_{PD}/N	-1.8351	-.0482	6.8953	.1200		-.1145	.0442	.191	.471
	(3.221)	(1.881)	(2.671)	(.805)		(.374)			
LOG Q^d_{FD}	3.1410	-.3671[a]					.3194	.477	2.250
	(15.747)	(4.769)							

NOTE: Absolute asymptotic t-values are given in parentheses below each parameter estimate.

[a]In the feed equation $FP_{U.S.}$ is not deflated by CPI.

TABLE 2. Estimated Elasticities of Demand with Respect to Farm Price, Income, Convenience, and Marketing Margins, Mean Level of Data 1955-1975

Elasticity of:	With Respect to:				
	$FP_{U.S.}/CPI$	$WLF_{U.S.}$	Y/N·CPI	IWR/CPI	IWPI/CPI
Q^d_{FR}/N	-.124	-1.056	.111	-1.361	
Q^d_{PD}/N	-.235	4.715	.666		-.250
LOG Q^d_{FD}	-.891				

NOTE: In the feed elasticity calculation, $FP_{U.S.}$ is not deflated by CPI.